Bill Williams River Field Assessment: Hydrology, Hydrogeology, and Geomorphology

by

William Jackson
and
Paul Summers

U. S. Bureau of Land Management

Service Center
Denver, Colorado

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The Yuma District requested assistance from the Division of Resources in the analysis and quantification of instream flow needs for the Bill Williams River Riparian Planning Area. This report summarizes field observations made during the week of June 27-30, 1988, of hydrologic, geomorphic, and hydrogeologic conditions on the Bill Williams River between Alamo Dam and the National Wildlife Refuge. Our preliminary instream flow recommendations are also provided. Previous assistance was provided in the design of a conceptual (water balance-based) approach to quantifying instream needs for the Bill Williams River (memo 1382 [D-471], May 16, 1988), and in the preliminary stratification of river reaches for field sampling purposes. Also, in a memo to the Phoenix District hydrologist dated July 7, 1988, we provided reduced cross-section data collected during the field review, and a reanalysis of the Alamo Dam streamgage data for the post-dam period. This report reflects, in part, the collective observations of the field team. Team members included Jim Nye (Yuma DO), Barry Long and Lin Fehlmann (Phoenix DO), Mike Henderson (Havasu RA), and Becky Peck (Kingman RA). Robert Brumbaugh and T.J. Stetz of the Corps of Engineers, and Dan ________ of the U.S. Fish and Wildlife Service also participated in the field assessment. Dave Ellerbroek, Norma Reitsma, and Shirley Hudson of the Division of Resources assisted in field data reduction.

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1. Hydrologist and hydrogeologist, respectively; Bureau of Land Management Service Center; D-470; Denver, Colorado 80225-0047

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Background

The Bill Williams River Riparian Management Area is located in the Basin and Range Lowlands physiographic province of western Arizona. The BLM-managed reach begins at Alamo Dan and runs roughly 35 miles downstream to the Planet Ranch (owned by the city of Scottsdale). Flows in the river are almost entirely regulated by the operation of Alamo Dam although ephemeral inflows and probably some underflow from tributary drainages occur unregulated. The reservoir's operation schedule calls for a 10-cfs base release or a release equivalent to reservoir inflows, whichever is less. Roughly 75,000 ac-ft. of stormflow are also released downstream. Post-dam discharge summaries at the Alamo Dam streamgage were provided to the Phoenix District hydrologist in a separate report. In general, median monthly flows reflect the reservoir operation schedule. Prior to dam construction in 1970, annual flows at the Alamo gage averaged 94 cfs. Baseflows (as indexed by the 90-day low flow) averaged 6.7 cfs.

In 1986, the state of Arizona (DWR) requested the Corps of Engineers to reevaluate the reservoir operation schedule. Subsequently the city of Scottsdale filed a water right application for the unappropriated stormflow releases, proposing that they be diverted from the Alamo Dam reservoir. In 1988, subsequent to the city of Scottsdale filing, BLM applied for an instream flow appropriation below Alamo Dam for flows ranging between 41 to 601 cfs, depending upon the month of the year. At the time of its filing, BLM indicated its intent to more thoroughly assess its instream flow needs and to modify its application if need be.

Hydrogeology of Bill Williams River

Ground water in the Bill Williams River Valley occurs primarily as underflow in alluvial basin-fill deposits that consist of boulder to pebble conglomerate with interbedded fine-to-medium-grained sands and silt deposits.

Geologic formations and structural features such as fractures that have been produced by faulting control the flow system. For example, the bedrock at the stream gage at Alamo Dam is very extensively fractured which allows some water to percolate downward from the stream into the regional aquifer. Reaches of gaining or losing stream are controlled by variations in bedrock and its proximity to the surface. The Planet Ranch area has been filled by gravels that probably contain rock fragments ranging in size from pebbles to large cobbles (1.25 in. to 10.08 in. using classification of Friedman and Sanders, 1978).

Streamflow losses along the reach from Alamo Dam to Planet Ranch are due mostly to geologic and geomorphic factors and do no represent large gains or losses in combined surface flow and underflow. Some losses are believed to be to the regional ground-water flow system, but these are not quantifiable without initiating a complex ground-water study. However, these losses are not believed to be very substantial.

In April 1951, the USGS made a seepage run along 30 miles of stream from Alamo to a rock constriction about 1 mile downstream from Planet Ranch. These data show that the stream was dry in Section 14 N.E. 1/4, T.10 N. 14 W.; however, the streamflow was measured at 10 cfs below Planet Ranch. The flow at the Alamo gage was 8.94 cfs (Wolcott, Skibitzke, and Halpenny, 1956); thus, no significant losses occurred that removed water from the alluvial aquifer system. The slight gain recorded at the gage site below Planet Ranch could be attributed to ground-water input from Castaneda Wash on the east side of the valley at Planet Ranch.

The Bill Williams Valley is believed to be formed along a fault zone that allowed for relatively rapid downcutting of the otherwise highly resistant metamorphic rocks. This explains the unusually dense fracturing of the bedrock in the vicinity of the Alamo gage.

The valley at Planet Ranch is capable of storing an astonishing amount of ground water. Having large dimensions (6 miles long x 1.25 miles wide) and thick deposits of alluvium that are very permeable, the valley can store large volumes of water without experiencing large changes in the ground-water level. Although well owners have reported fluctuations of water level of as much as 30 ft. (Sanger and Littin, 1981), this is most likely due to ground-water mounding effects near the river. Such rises in the ground-water level probably do not occur very far away from the river channel.

The storage volume can be calculated using the equation V=SAdh, where S=storage coeficient, A=surface area, and dh=the change in head in the aquifer. For example, if the water level is raised by 1 ft. in the valley

fill, the amount of additional water taken into storage would be 312,855,420 gallons. Using the following equation:

$$V=SAdh$$

where: $S=.20$

$A=7.5$ sq. mi.

$dh=1$ ft.

$V=312,855,420$ gal.

The cross section at Site 7 (at the east of Planet Ranch Valley) was used to determine the quantify of underflow that is passing into the Planet Ranch area. This site represents a reach of the stream where riparian vegetation has existed (but has been reduced due to livestock) and is particularly useful because of the straight reach and the well developed floodplain. The volume of water flowing through the alluvial deposits as underflow can be determined using the Darcy equation Q=KIA, where K is the hydraulic conductivity, I is the hydraulic gradient, and A is the cross-sectional area perpendicular to the flow path. Using a value of K=31.2x10-3 for coarse gravel (Mercer, Thomas, and Ross, 1982), which should be representative of conditions at this site, the flow of 28 cfs through the alluvium can be accounted for.

Using the following equation:

$$Q=KIA$$

where: $K=31.2 \times 10^{-3}$

$I=.002$

$A=(912 \text{ ft.} \times 150 \text{ ft.})$

$Q=18{,}100{,}763$ gal/day

$=12{,}569$ gal/min

$=28$ cfs

If the hydraulic gradient is actually greater than .002 or if the thickness of the deposits is greater than 150 ft. (a more likely situation), then the underflow could approach the 80 cfs loss that we observed at the west side of Planet Ranch in the canyon outlet during the field measurement in June 1988.

The surface-water flow system at the outlet of Planet Ranch does not respond to large changes in inflow at Planet Ranch by producing corresponding increases in surface flow. This is because of (1) the extremely large storage capacity of the alluvial sediments, (2) the very high hydraulic conductivity of the sediments, and (3) the geologic control at the outlet.

The geologic control at the Planet Ranch outlet is an interesting one and has its origin in the postulated faulting that occurred several hundred thousand years ago. As mentioned earlier in this section, the Bill Williams River is believed to follow the trace of a fault or a zone of faulting that produced a

line of weakness where the river rapidly cut down into the bedrock. Over thousands of years, downcutting likely produced a notch in the bedrock prior to filling the valley with sediment. This notch controls the rate of outflow from Planet Ranch downstream to the refuge. This factor, combined with the fact that great increases in water level in the sediments generally do not occur, accounts for the observed flow out of Planet Ranch being maintained at about 10 cfs no matter what the inflow is at the east side of Planet Ranch. Data taken by USGS (1951) confirms this outflow rate. The flow was at about 11 cfs during this study when the release from the dam was 100 cfs. The effect of all this is that the Planet Ranch Valley acts similar to a constant head boundary at that point in the flow system. Large inputs to the system at this point are moderated by the extremely high storage capacity of the fill. A nearly constant flow rate out of the valley downstream is the result.

In addition to the inflow to Planet Ranch from the river, there is a contribution from ground-water flow at Castaneda Wash. Water level data in one well about 6 miles north of Planet Ranch indicated a water level of 679 ft. (Sanger and Littin, 1981). This confirms a ground-water gradient exists between the well and the valley fill at Planet Ranch where the water level in wells is generally at 605 ft. However, a hydrogeologic connection is not confirmed at this time because we don't know enough detail about perched aquifers or multiple aquifers that may confound water level measurements and result in an erroneous interpretation of the hydrogeologic system. The potential for large contributions of flow via ground water from this source is very great; there is an extremely large drainage basin that extends north from Planet Ranch for about 10 miles. This area is covered with Tertiary and Quaternary sandstone, conglomerate, and unconsolidated sand gravel. It is our

belief that large contributions might be input to the Planet Ranch area from this drainage basin. The contributions are likely highly variable and likely exhibit much seasonal fluctuation.

This hydrogeologic flow system that provides water to Planet Ranch needs to be evaluated more fully if a clear understanding of the river dynamics and the ground-water/surface-water interactions is going to be achieved. However, for purposes of this study, the quantification of this component is not critical to the analysis. It may become an important factor if ground-water pumping at Planet Ranch is increased substantially. An accurate and complete accounting of the water balance might then be necessary.

Geomorphic Conditions

The Bill Williams River in the study reach is an alluvial stream, with a very mild gradient. The mild gradient combined with the presence of riparian vegetation and--we believe--the historic presence of beaver, provided the depositional environment for sediments delivered from tributary drainages. Barren watershed conditions, combined with the steep tributary drainages and the ephemeral nature of runoff, resulted in considerable coarse sediment delivery. The alluvial valley bottom is subsequently coarse grained and very permeable. Where the valley fill is deep and wide, for example at Planet Ranch, considerable volumes of water can be stored and transported via underflow in the alluvial sands and gravels. Where the valley is narrow, for example at the gorge below Alamo Dam, alluvial deposits, though coarse, have lower storage capacity due to their smaller cross-sectional area and won't transmit high volumes of water as underflow.

As is typical of alluvial (depositional) streams, the Bill Williams River below Alamo Dam was historically characterized by lateral adjustment and migration. Features and processes such as meandering, bar development, channel migration, braiding, and channel realignment were probably common and are still abundantly evident below Lincoln Ranch.

Following construction of Alamo Dam, runoff peaks and sediment transport rates were greatly reduced. The stream channel responded to the decreased upstream sediment inputs by downcutting between Alamo Dam and the lower end of Lincoln Ranch. The streambed in this reach is now well controlled by cobble and boulder-sized materials. Width-to-depth ratios have been reduced, and main channel capacities have increased--meaning that few, if any, high flow releases now have access to the historic floodplain and riparian zone.

Downstream from Lincoln Ranch, the stream is adjusting to the reduced high flows by aggrading its bed (sediment inputs--both from the scoured reach upstream, and from side drainages--now exceed the transport capacity of the river). The streambed is composed primarily of sand and fine gravels. Width-to-depth ratios increase dramatically, and main channel capacities appear to be lower. High flow releases have access to much of the historic floodplain and riparian zone downstream from Lincoln Ranch. Ongoing depositional processes are very pronounced in the vicinity of Planet Ranch/Centennial Wash--and are accentuated by the dramatic reductions in streamflow and sediment transport capacity in this reach.

Channel conditions and sedimentation processes interact significantly with riparian area conditions in the reach below Lincoln Ranch. Stream channel and floodplain conditions will be enhanced by riparian area conditions in this reach. Conversely, riparian vegetation will benefit from controlled channel adjustments and modest, periodic flooding.

Generalized Water Balance

A generalized water balance for the Bill Williams River study reach is depicted in Figure 1. Inputs occur primarily as releases from the Dam, with some limited volume tributary surface-water flows and ground-water inputs also occurring at various locations downstream. Outputs occur as (1) consumptive use by riparian vegetation, (2) evaporation, (3) percolation to deep ground water, (4) consumptive use for agricultural and domestic purposes, and (5) outflow at Planet Ranch. Outflow to Planet Ranch occurs as both surface flow (low volume) and ground-water flow through the stream alluvium (underflow).

Flow in the river at any place and point in time reflects not only inputs and losses, but a strong interaction between surface flows and underflows. Where valley bottom alluvium is deep and wide, underflow capacities in the alluvium are large and surface flows are reduced by percolation into the alluvium. Conversely, where valley bottom alluvium is shallower and more confined, underflow capacities are reduced and surface flows increase. As explained above, the substantial loss of streamflow through the canyon below Alamo Dam is probably explained in part by losses to deep ground water through fractured bedrock. Losses in the vicinity of Centennial Wash, below Cross Section BW-6, are probably explained by increased underflow volumes. The enormous losses

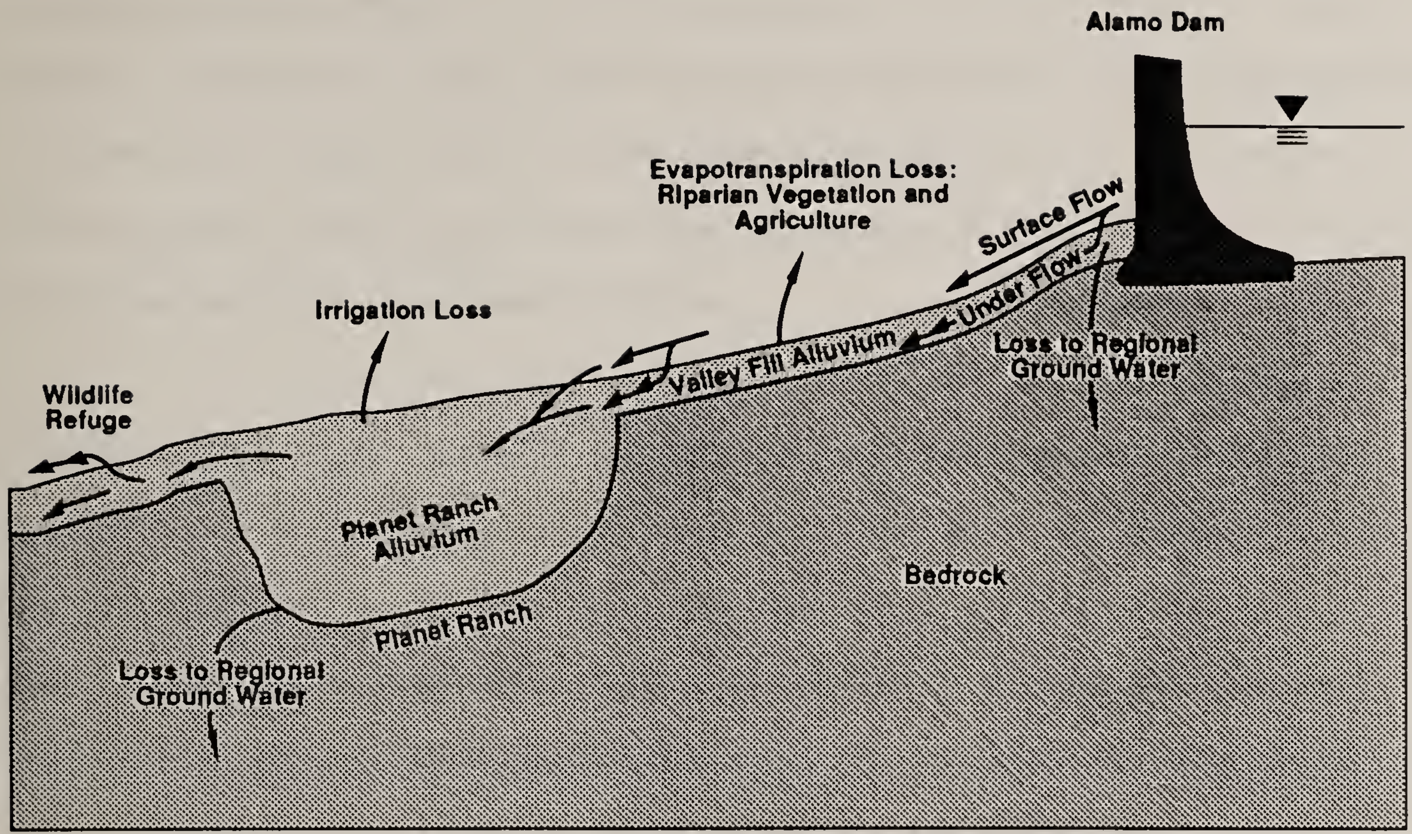

Figure 1. Conceptualization of major components of Bill Williams River water balance.

that occur at Planet Ranch are explained primarily by the very large storage volume and high permeability of the alluvial fill in the valley at Planet Ranch. Substantial losses to the regional ground-water flow system may also account for a large portion of the total flow declines that are observed. Further study needs to be done on the interaction of the Bill Williams River with the regional ground-water system.

Based upon our field observations and discharge measurements, and drawing from water budget data developed for the city of Scottsdale (Bill Stephens and Assc., 1988), it is our best judgement that roughly 10 cfs are required to meet evapotranspiration needs (riparian vegetation and agriculture) and percolation to deep ground water. Releases in excess of 10 cfs probably make it to Planet Ranch--either as surface flow or underflow. High releases probably recharge somewhat the floodplain aquifer in the study reach, and contribute to subsequent discharges to Planet Ranch. Similarly, high flows will provide substantial recharge of the alluvial aquifer beneath Planet Ranch because of the aquifer properties discussed above. We believe the present baseflow release of 10 cfs from Alamo Dam is inadequate in and of itself to meet downstream uses and losses (including those at the Wildlife Refuge and at Planet Ranch). Water use by the Refuge and Ranch, in particular, have been maintained to a great degree by shallow aquifer recharge resulting from periodic higher-flow releases from Alamo Dam.

Riparian Condition and Potential

We believe the present deteriorated riparian conditions observed in the study reach cannot be attributed to the post-dam release schedule, but rather are the result of (1) geomorphic adjustments (described above) which occurred as the result of dam construction, and (2) effective management of livestock grazing in the riparian zone. However, we caution that altering the reservoir release schedule to reduce stormflow-period releases without compensating somewhat by increasing baseflow releases could adversely affect downstream water supplies and uses.

Presently, the best opportunities to enhance riparian conditions occur downstream from Lincoln Ranch, where channel capacities and floodplains are still in balance, and where riparian zone water tables are still intact due to a well developed floodplain. In addition to the broad alluvial zone in the vicinity of Centennial Wash, we would suggest that reaches of "gaining" streamflow downstream from Cross Section 3 might, from a water standpoint, have good riparian potential.

Recommendations

Instream Flows:

It is our best judgement that a 20-cfs base release from Alamo Dam, combined with a 110-150 cfs high flow release in March, would be a minimum volume to meet downstream and instream water requirements, including maintenance of the

Planet Ranch aquifer, small baseflow releases to the National Wildlife Refuge, and enhanced riparian vegetation conditions in the BLM project area. Our water budget determinations suggest that a 20-cfs release would still result in the stream drying up in the vicinity of Centennial Wash during the growing season. However, we believe underflow in that reach would still be sufficient to maintain riparian water tables.

A 30-cfs base release would be an "optimum" release because it would maintain perennial flows throughout the project reach. This clearly would influence fishery and recreation values in reaches that otherwise would dry up. Under a 20-cfs release, however, instream flows would still be adequate to maintain and even enhance the present fishery (which has been established under conditions of a 10-cfs base release). The wetted perimeter data (provided under separate transmittal) suggest that a base flow between 5 and 25 cfs is adequate for fishery purposes. Flows between 5 and 20 cfs would be common above Cross Section BW-6.

The present 10-cfs release would, we believe, be inadequate to both maintain the existing fishery and enhanced riparian conditions, as well as downstream (Planet Ranch, Lincoln Ranch, Wildlife Refuge) needs, without frequent higher-flow releases as have occurred under the present operation schedule).

The 110-150-cfs March release is required for fine sediment flushing (the 105-cfs release was observed to be effective in transporting sands and fine gravels), fish spawning, and vegetation reproduction and establishment. Floodflow releases, which can be expected to occur periodically, should be adequate to maintain morphological features associated with channel adjustment and migration.

Land Use

Deteriorated vegetative conditions, resulting from ineffective livestock management, were observed throughout the study reach. Concomitantly, we observed vigorous cottonwood reproduction in reaches presently receiving rest from grazing. We believe it is essential that range management expertise be effectively represented on the Bill Williams Riparian Management Planning Team to assist in the evaluation of riparian conditions, the formulation of management objectives, and the development and evaluation of management alternatives.

Water Rights

The quantification in the present BLM water rights application is in error. That application should be formally modified at an early date to reflect numbers more in line with those determined by this project. This would indicate BLM's intent to be a reasonable party in discussions concerning the operation of Alamo Dam. Also, BLM needs to establish a constructive dialog with the Corps of Engineers, city of Scottsdale, National Wildlife Refuge, and state of Arizona concerning the allocation of water from Alamo Dam.

Additional Study

We believe the information gained during the field reconnaissance is adequate to support an instream flow water right application. Additional information, however, could further refine the quantification and substantiate our release recommendations. First, it is likely that water balance losses, to some

extent, are a function of reservoir releases and season. Quantification of losses at other releases and at other times of the year could better develop our understanding of this phenomenon.

Secondly, we presently cannot distinguish--other than intuitively--between vegetation water requirements and losses to groundwater or throughflow. Quantification of losses during the vegetation dormant season could help quantify the components of water "loss."

Third, the status of the riparian water table in the Centennial Wash area and at Castaneda Wash needs to be established at times when surface flows are not present. Shallow observation wells could determine whether ground-water underflow in the alluvial channel is sufficient to maintain riparian vegetation, and whether seasonal fluctuations in the water level are significant.

Finally, evaluating zones of surface flow under the 10-, 20-, and 30-cfs baseflow release alternatives during both winter and summer seasons, could provide additional information on surface-water/ground-water interactions.

Again, we reiterate our belief that the team's field reconnaissance was very informative and productive, to which we credit all the individuals involved. The enthusiasm of all participants during this field study helped to make the study a great success. The hydrologic, hydrogeologic, and water rights issues on the Bill Williams River are very interesting. We thank you for involving us in this project and look forward to helping in the future in any way we can.

APPENDIX I

Bill Williams River
Summary Field Data[1]
June 27-29, 1988

Cross Section	Discharge, cfs	Inflection (Wet. Perim.-Q), cfs
1	105.5	15
2	91.0	19
3	86.4	8
4	93.9	15
5	93.7	not clear
6	86.2	no survey
7	76.1	10 est.
8	10.9	18
9	5.6	no survey

1. Complete cross section survey results were sent to the Phoenix District hydrologist under separate cover.

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